Coral Reefs, Climate, & Coral Bleaching
June 18 – 20, 2003
Turtle Bay Resort Hotel, Oahu, Hawaii

# The Hydrodynamics of a Bleaching Event

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Contributors:

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Lance Bode & Luciano Mason


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# Overview

Mixing - important?

Bleaching event - Hydrodynamics
- Modeling SST

Hydrodynamics - Reef induced mixing
- Model scales


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## Talk outline

Mass Coral Bleaching in 1998 and 2002– primary link with SST
NOAA AVHRR stuff – sgbr sst, ray's maps over sst, terry's validation

SST complexity explained by mixing processes
Need a knowledge of the environment – weather - both atmospheric and oceanic

Mixing models - spawning aggregations, fronts, turbidity, productivity

Physical controls on heating by mixing processes:
Wind, currents – tides and low frequency, CSW, waves

Source of cool water – upweling & subsurface intrusions and upwelling

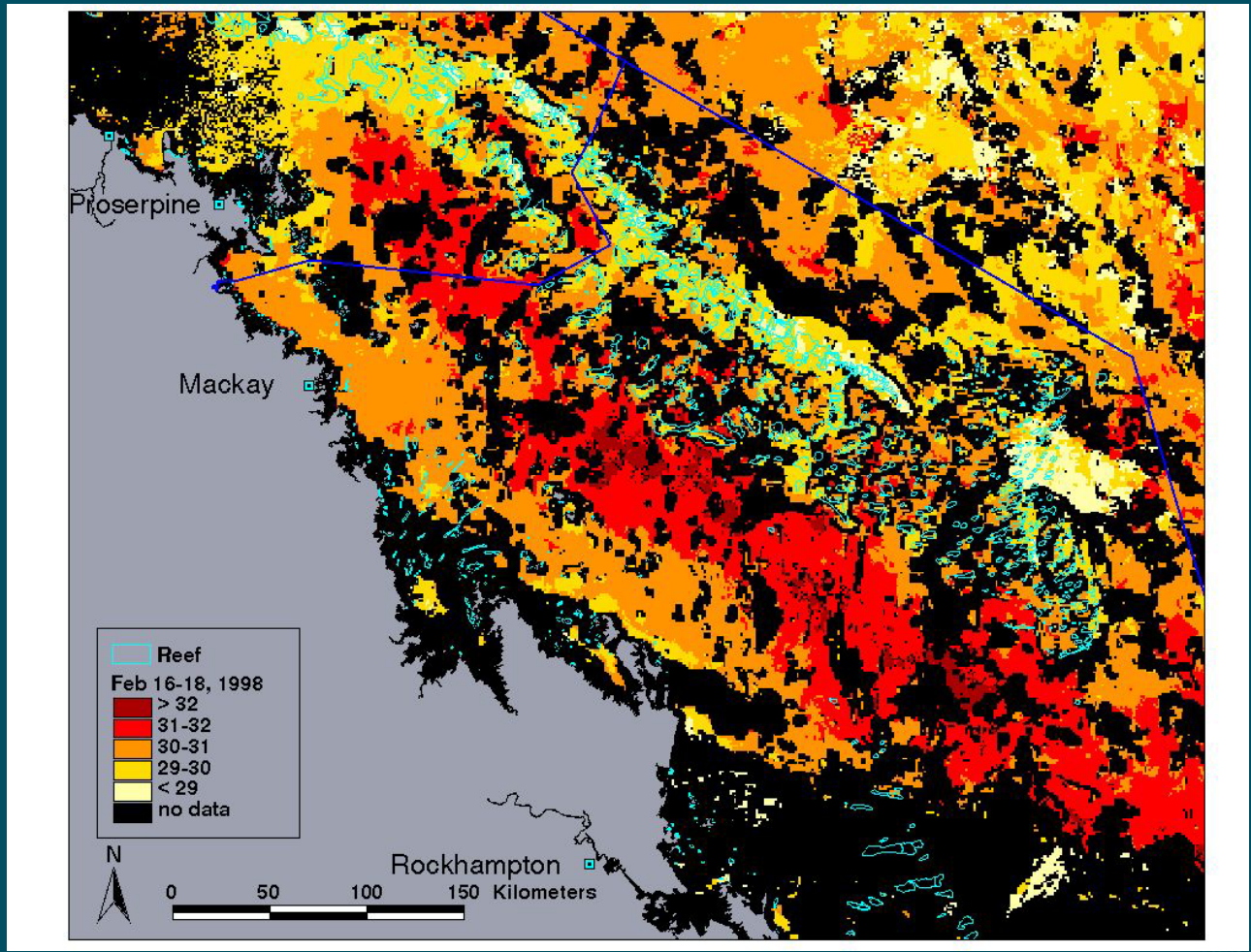
Stepwise approach
1d – formation of the surface heat layer
2d – spatial currents and bathymetry allow an idealised regional to reef-scale model
3d – baroclinic – explore ameliorating mechanisms – upwelling/intrusions

Sub reed scale temperature – davies, scott & heron
Davies locations, data – from sbe39

Connectivity
Larval dispersal, gene flow

# Hydrodynamic Mixing

## Southern GBR SST for 16th to 18th Feb 1998

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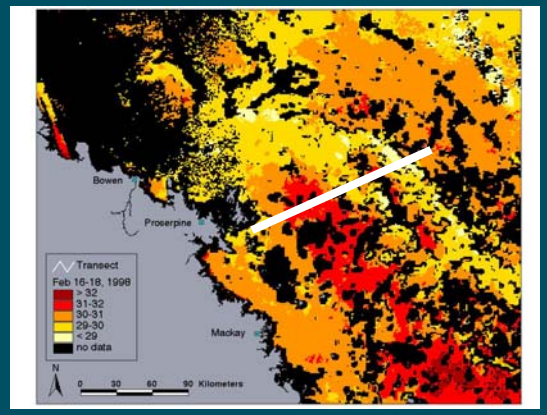
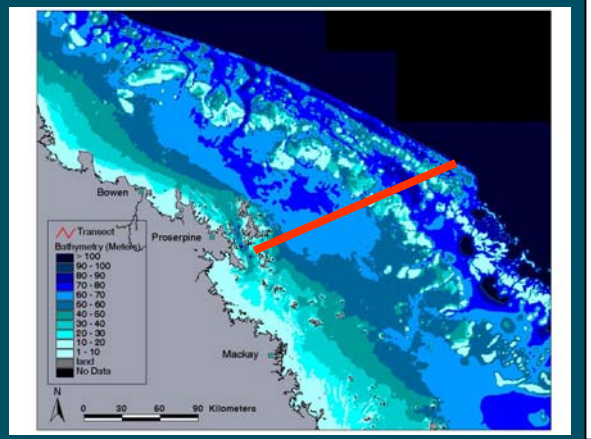
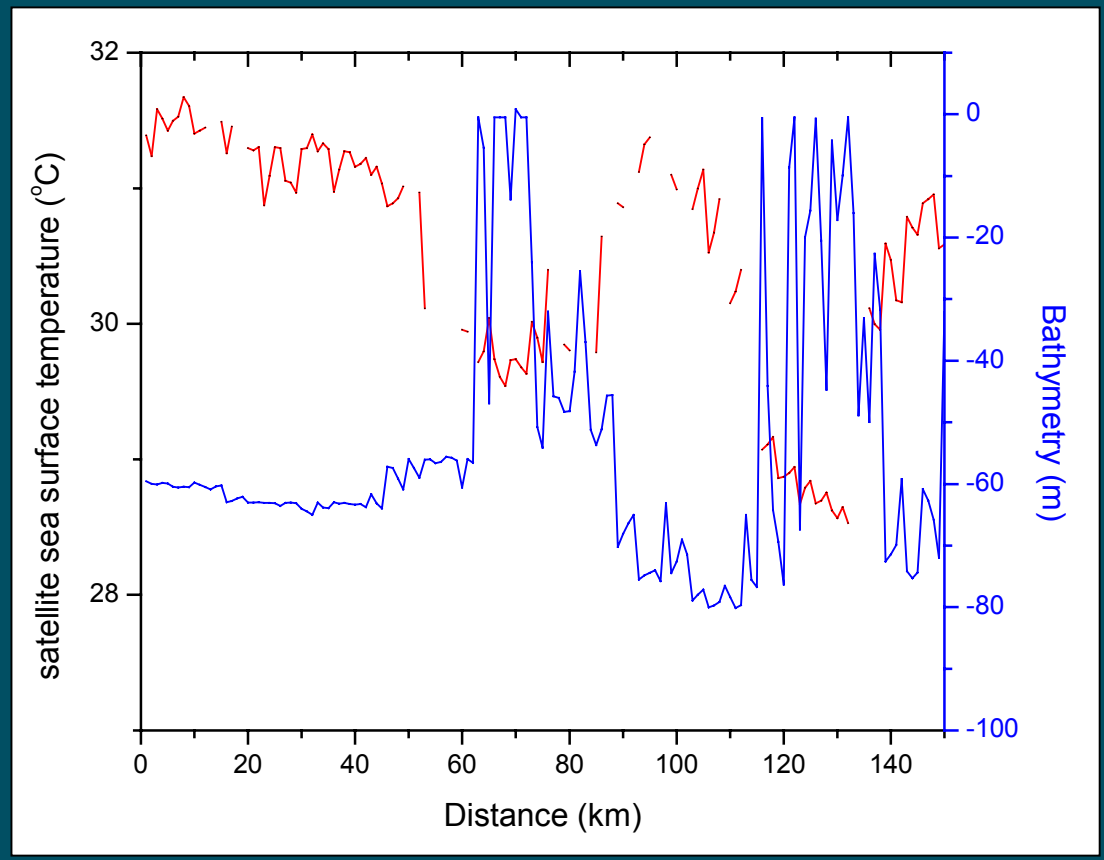
# Hydrodynamic Mixing

## Southern GBR Temperature transect 16-18 February

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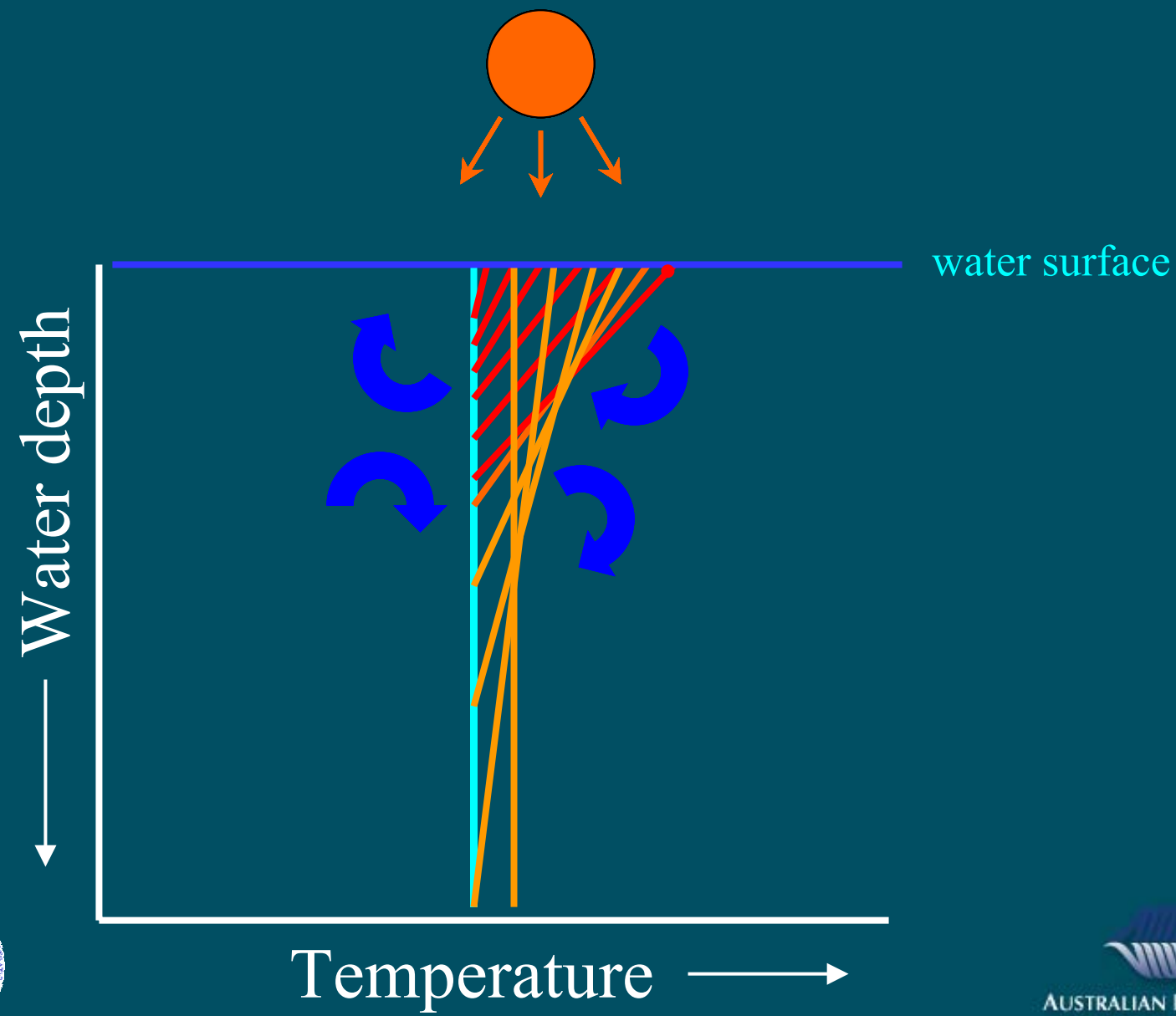
# Why is Mixing Important?



# Hydrodynamic Mixing

Mixing mechanisms:

- Wind
- Low frequency currents (eg East Australian Current, Gulf Stream)
- High frequency currents (tides)
- Swell waves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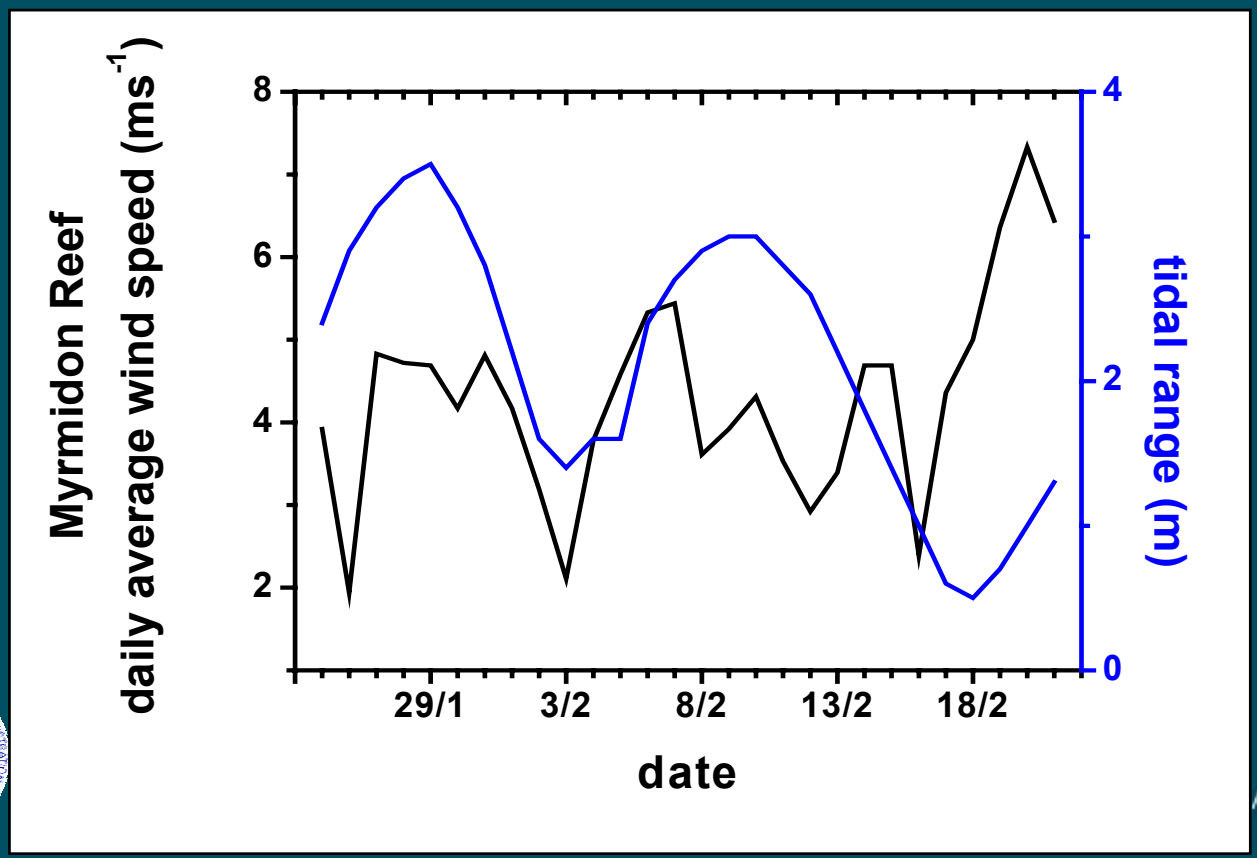
# Bleaching weather

## Myrmidon Reef daily average wind speed and maximum daily tidal range

*25th January to 21st February, 1998*

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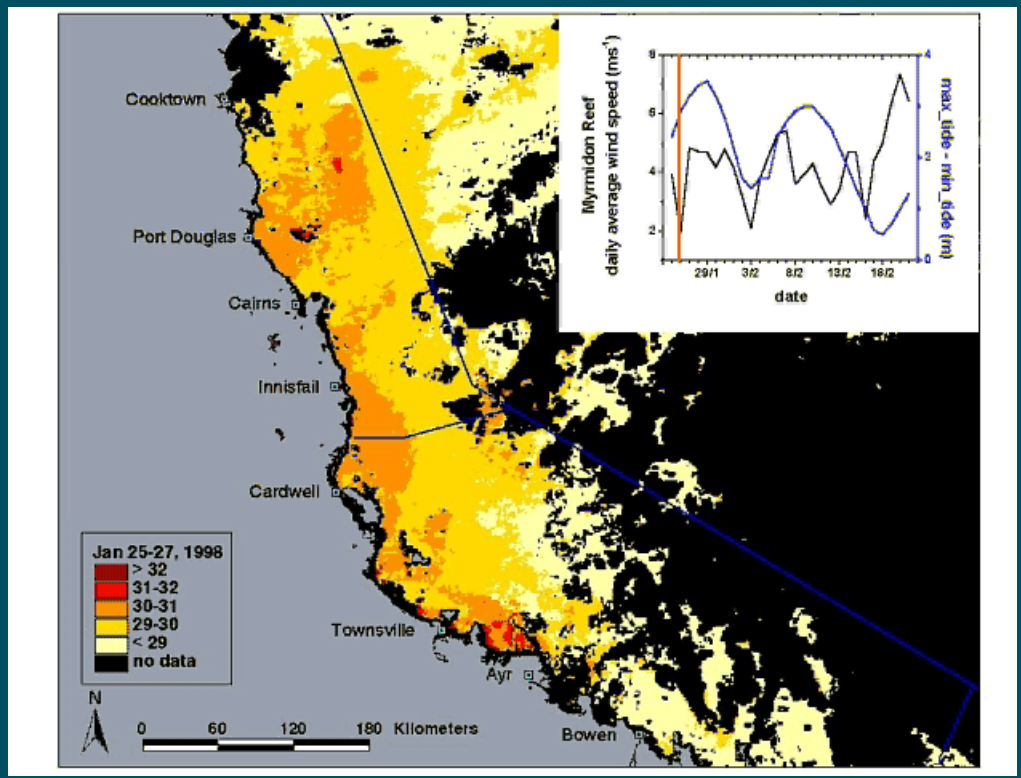
# Bleaching weather

## Animation of SST for 25th Jan to 21st Feb 1998

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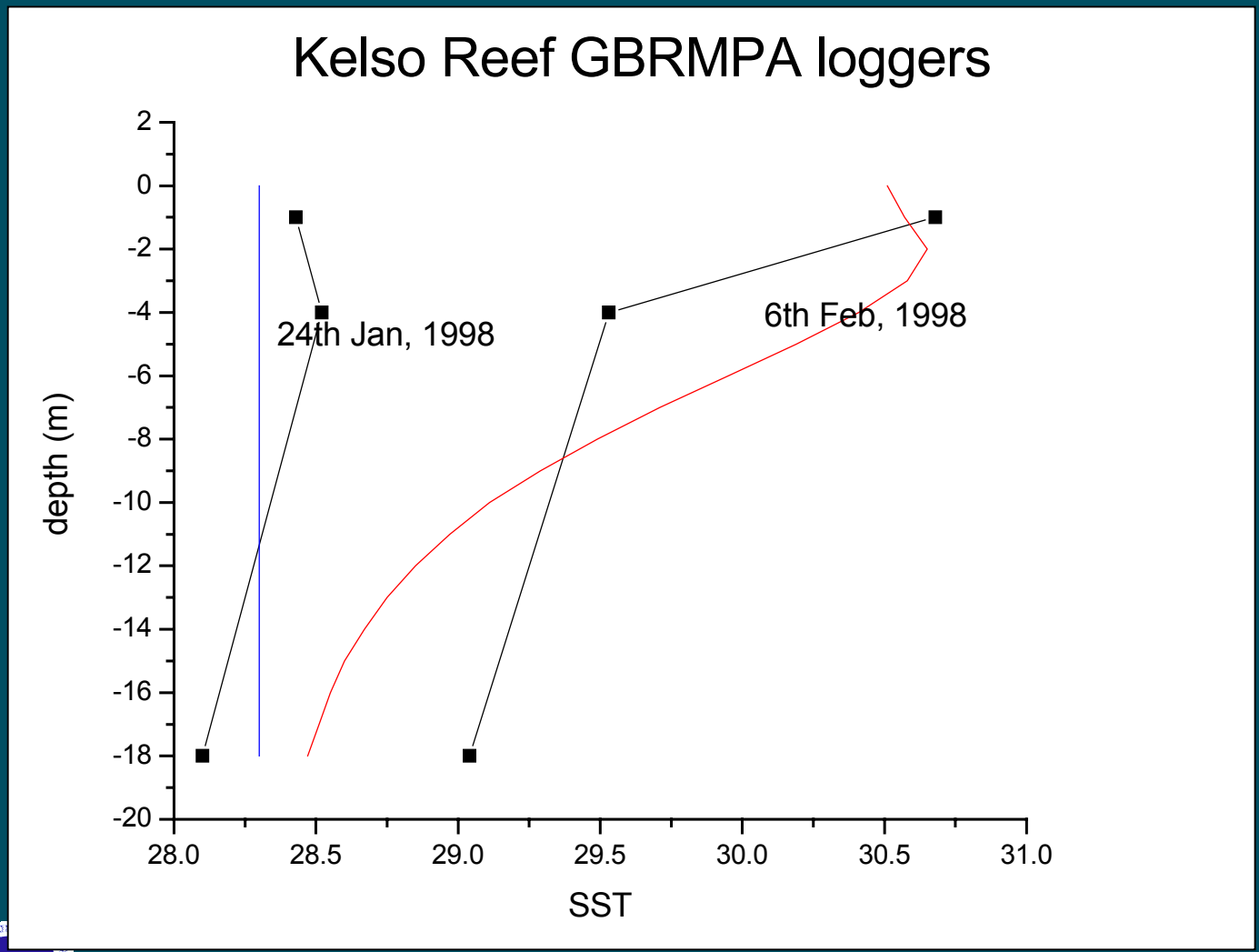
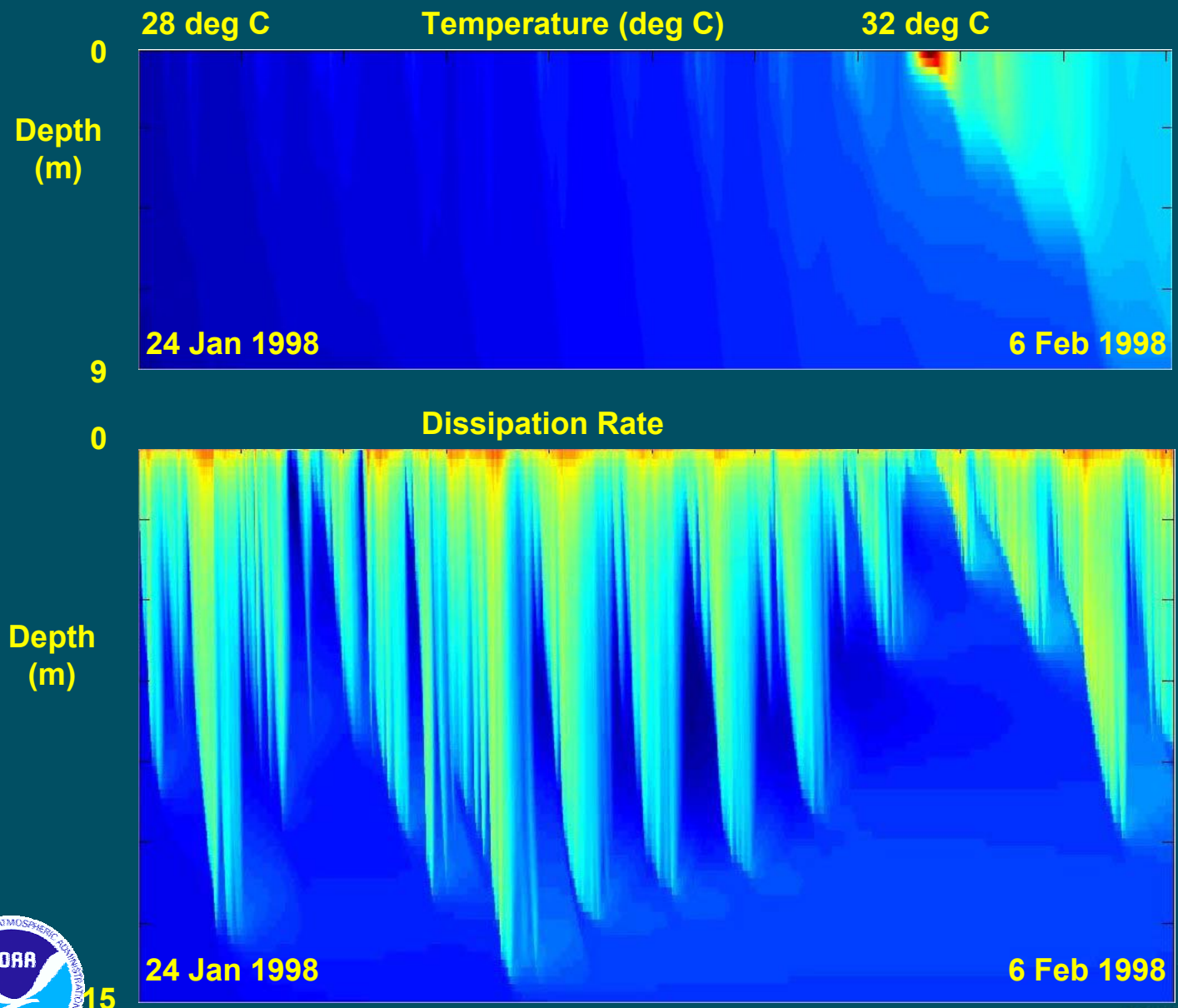
# TEMPERATURE PROFILE



# 1-D modelling – Development of Stratification

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# Bleaching Weather

1. Little to no wind
2. Clear sunny skies
3. Weak currents


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# Hydrodynamic Mixing

Mixing mechanisms:

- *Wind – not during bleaching*

- Low frequency currents (eg East Australian Current, Gulf Stream)
- High frequency currents (tides)

- Swell waves


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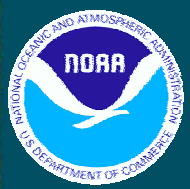
# Modeling swell waves

Preliminary research has shown that a 1m wave with a period of 8 seconds will mix to a depth of 50 metres in less than half a day. On average, this would translate to a surface temperature drop of 3 $^{o}$C on the exposed side of an outer reef of the Great Barrier Reef during the 1998 bleaching.

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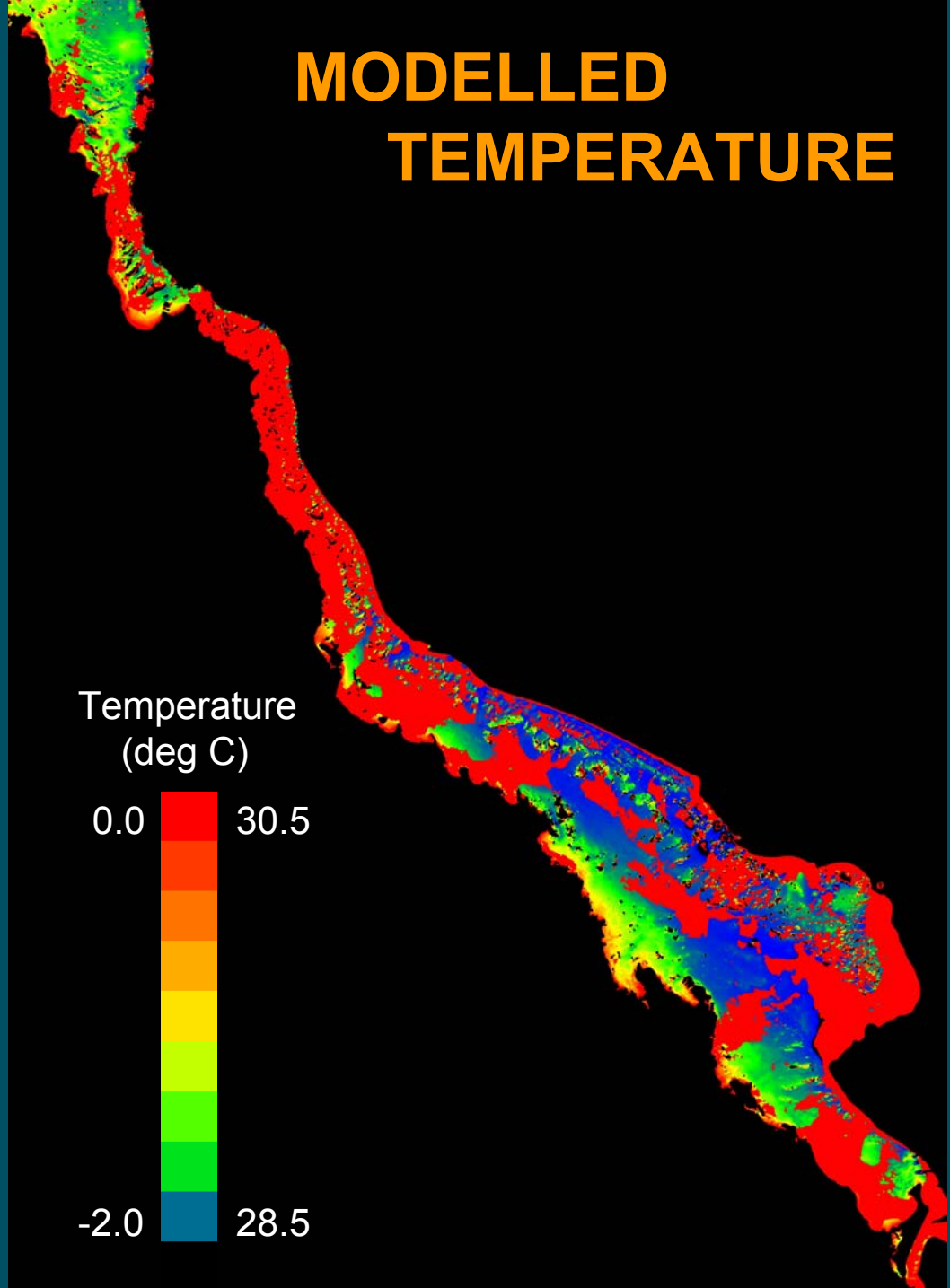
# MODELLED TEMPERATURE

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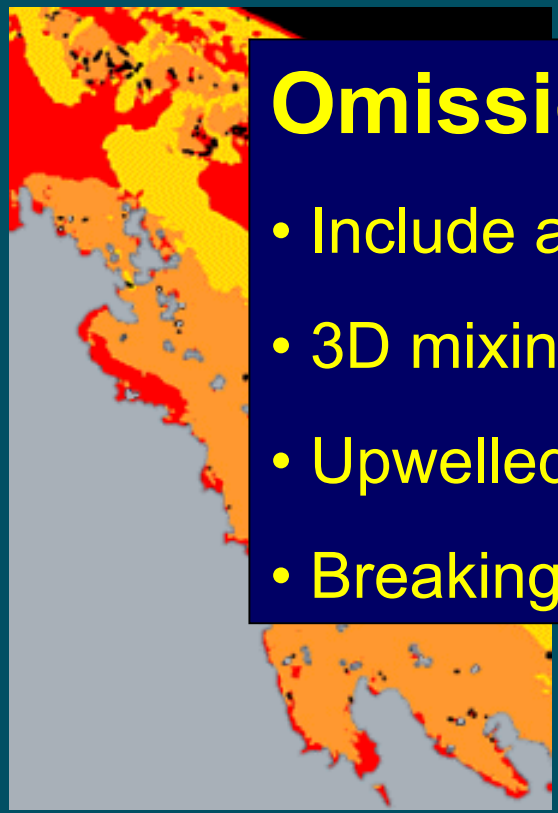
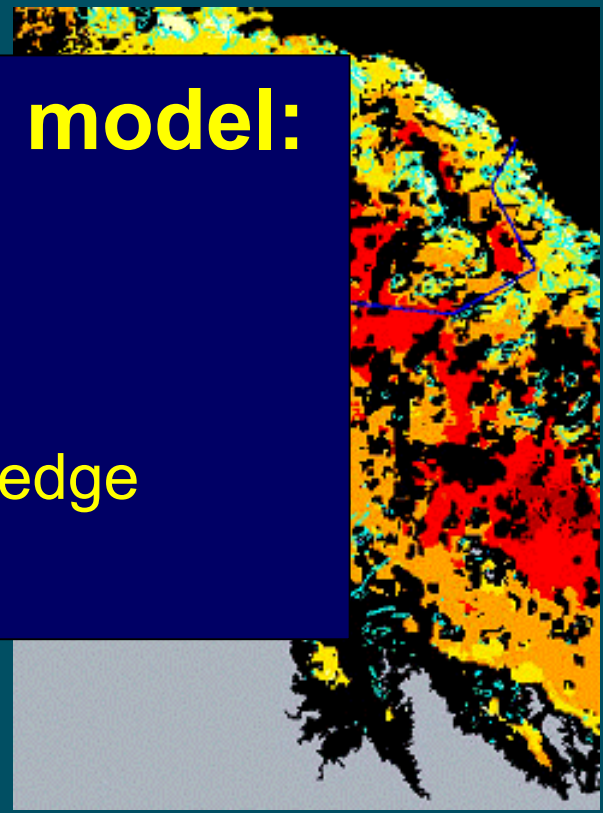
# Modeling currents for bleaching SSTs



Model



Satellite SST

**Omissions from the model:**

- Include advection
- 3D mixing behind reefs
- Upwelled water near shelf edge
- Breaking internal waves

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# Mixing in the GBR

Whitsunday

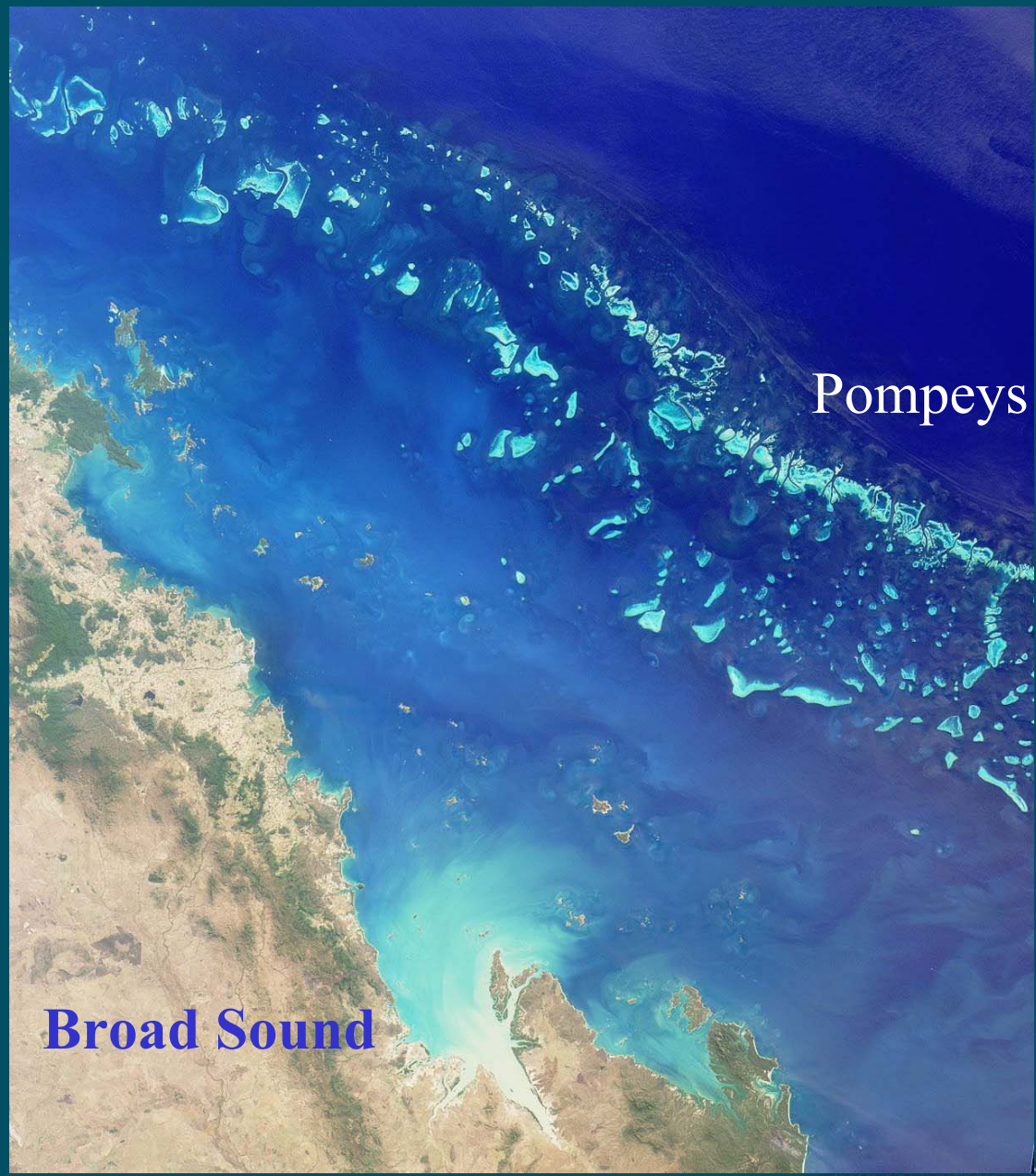


Image courtesy
NASA/GSFC/LaRC/JPL,
MISR Team

# Mixing in the GBR

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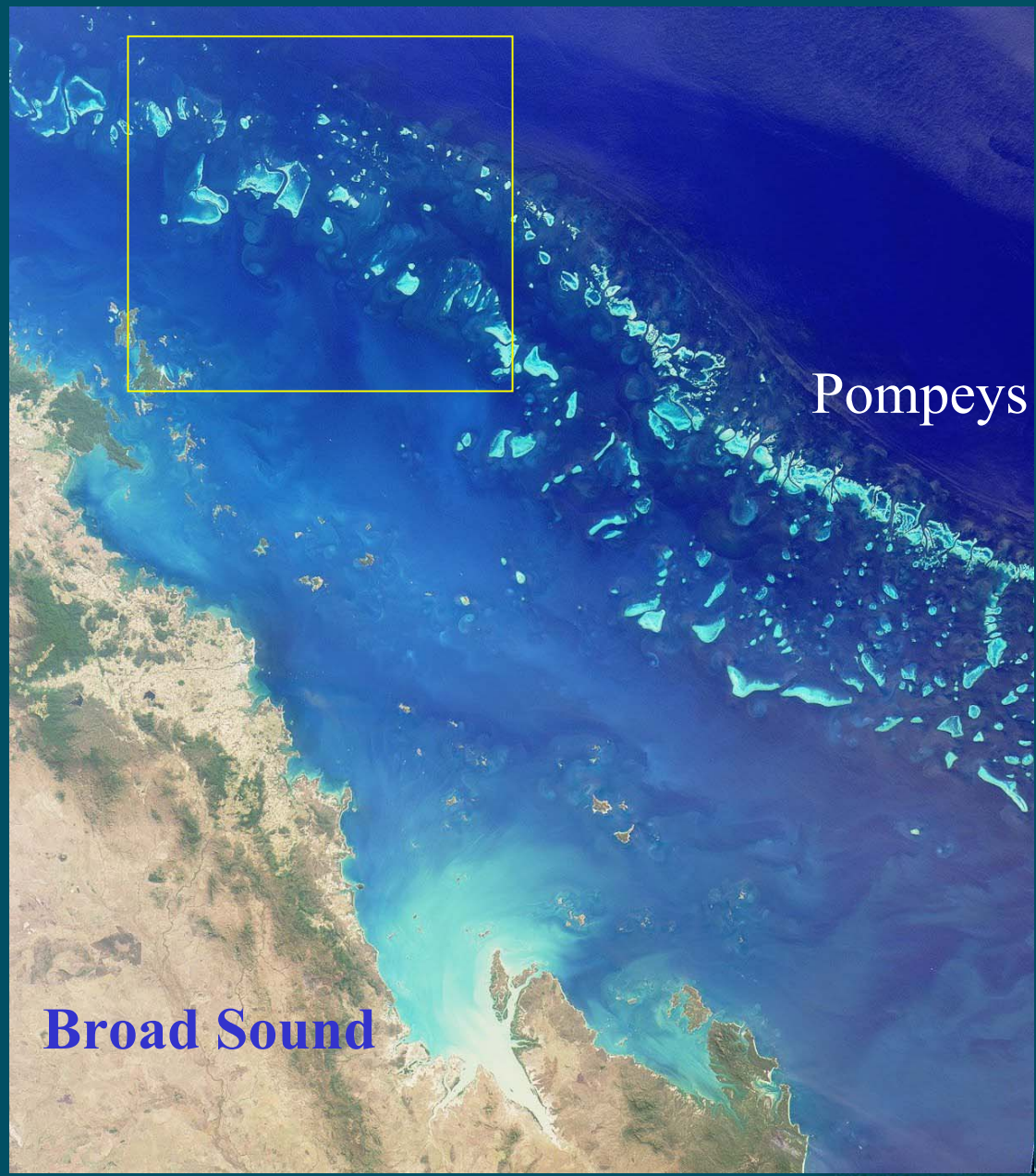


Image courtesy
NASA/GSFC/LaRC/JPL,
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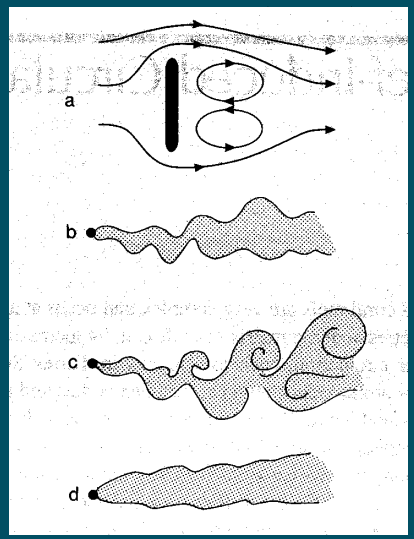
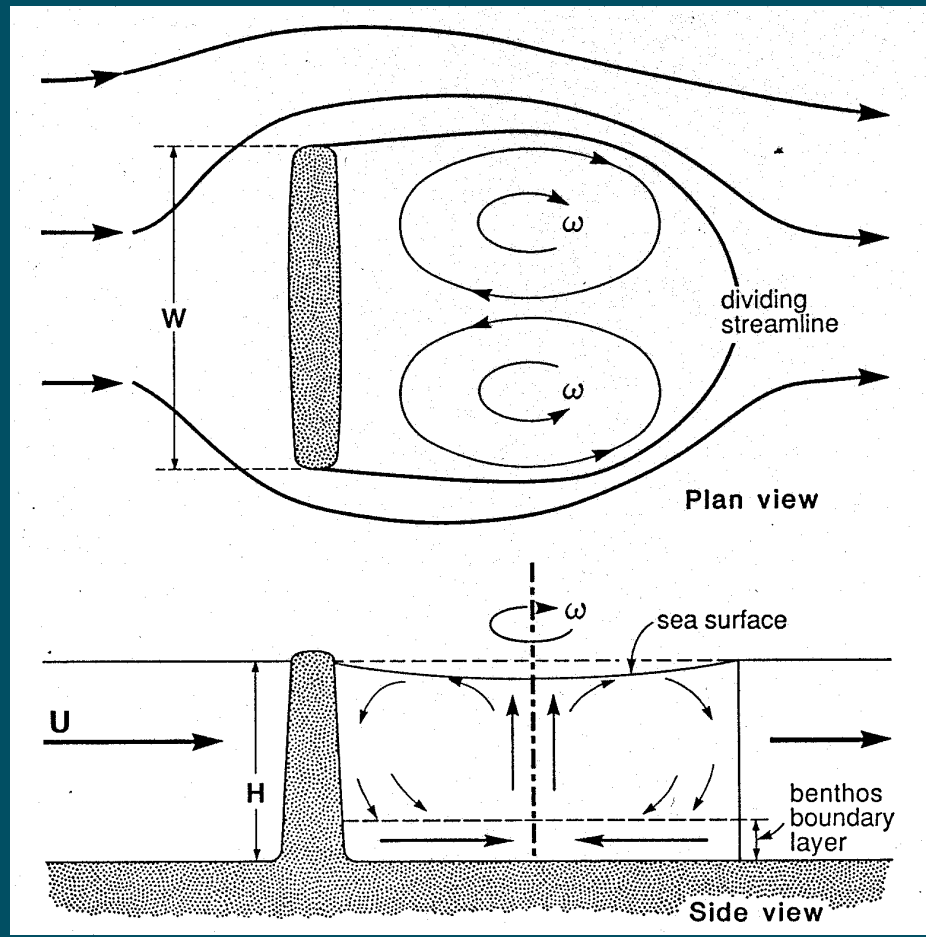
# Mixing in the GBR

# Coral Reef induced mixing

30 km




$$\mathrm{Re} = \frac{UW}{\nu}$$




a Re < 1 No flow separation
b Re > 1 Steady wake with eddies in the lee
c Re > 20 Flow instabilities form
d Re >>20 Meandering far down stream
Karman vortices are shed

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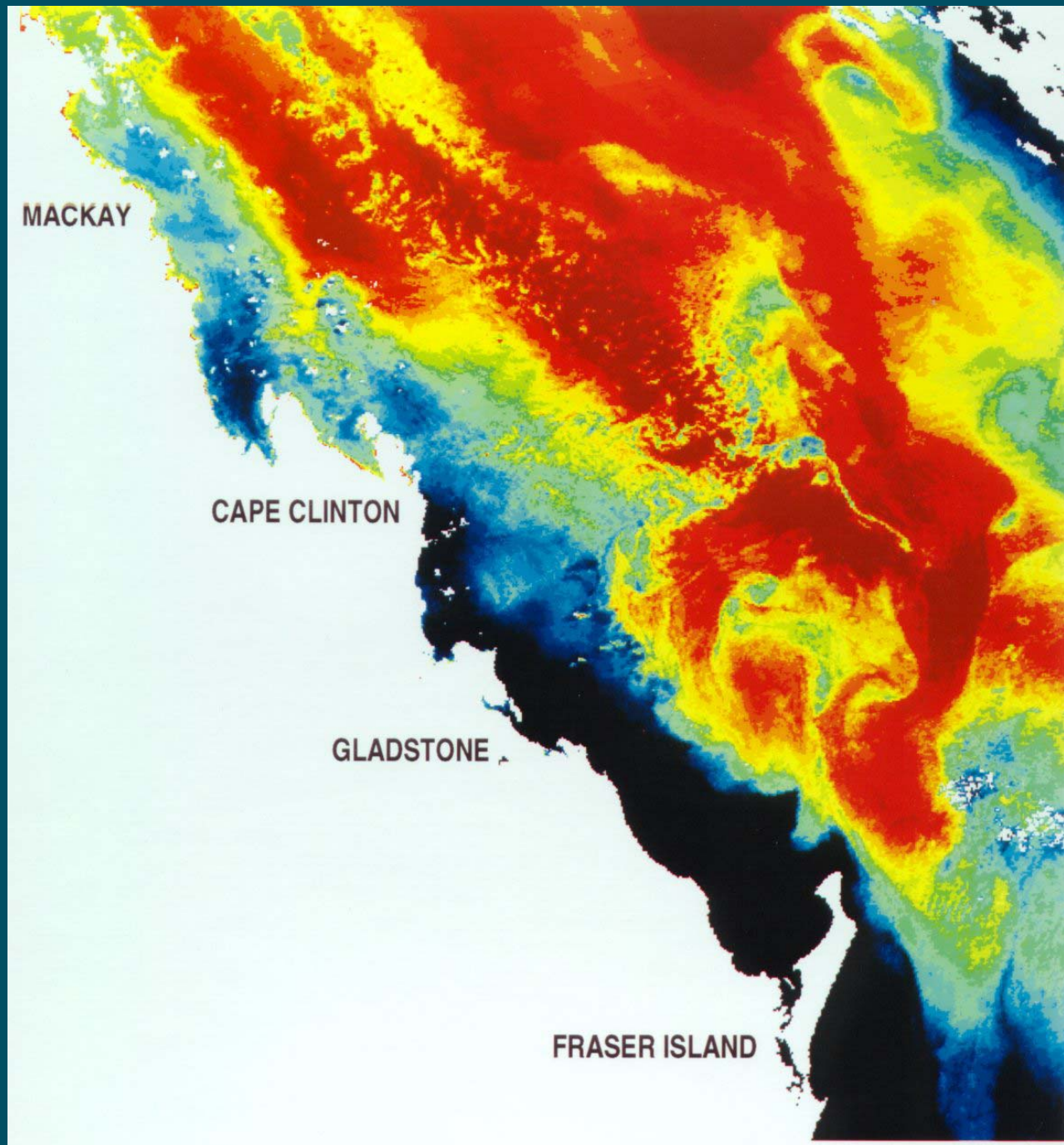
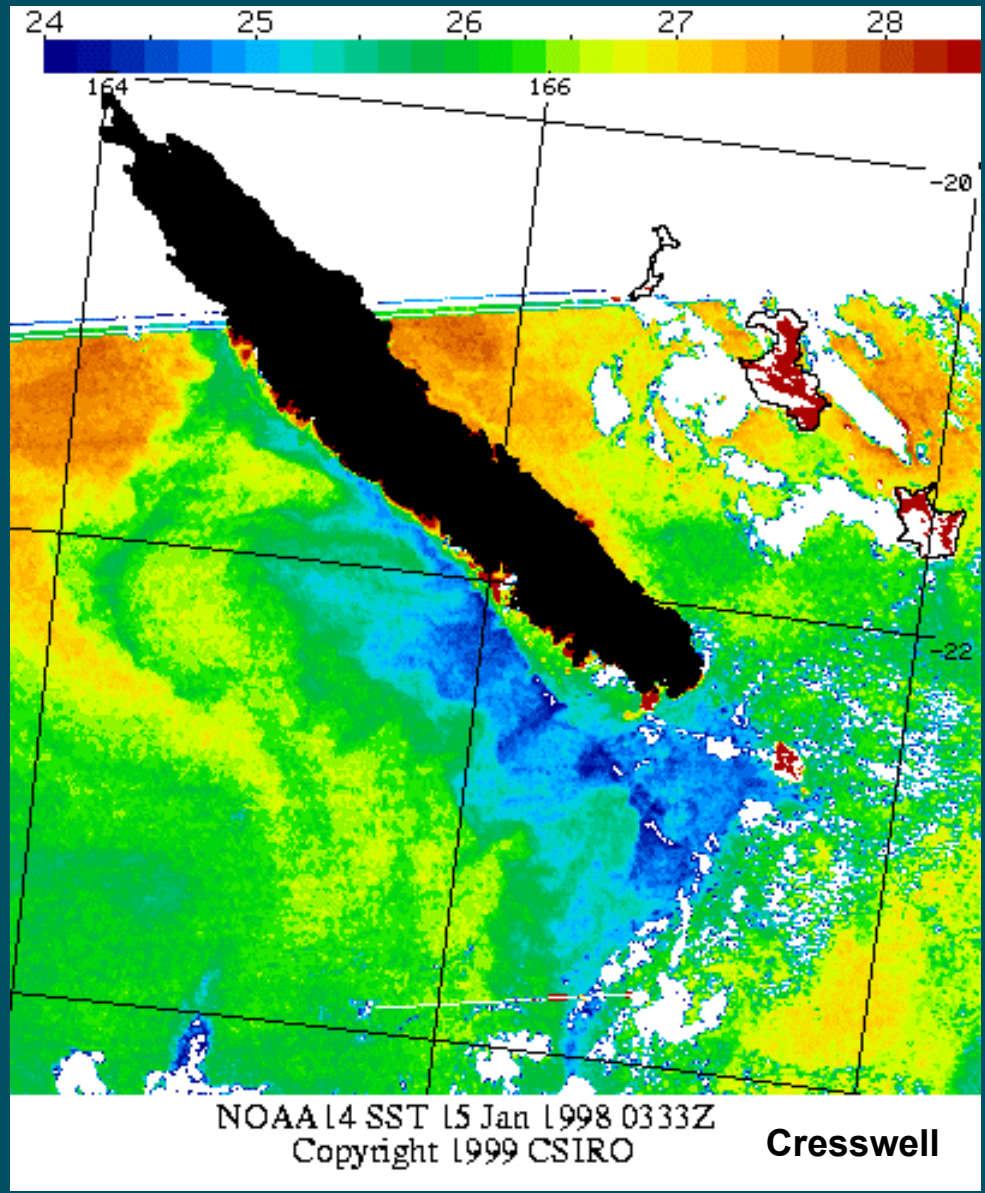
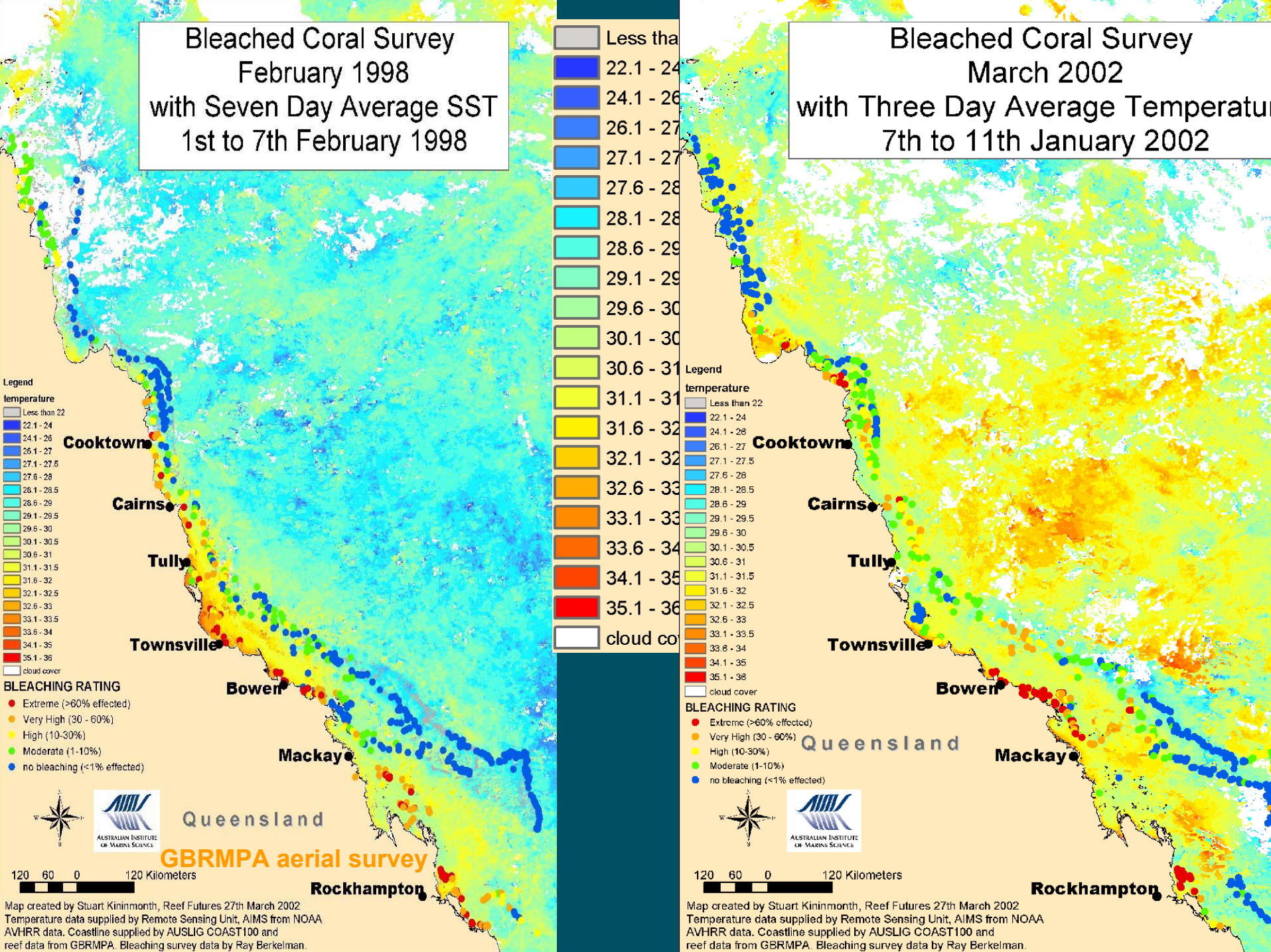
# SST of the GBR



# Upwelling : New Caledonia




Bleached Coral Survey
February 1998
with Seven Day Average SST
1st to 7th February 1998
Legend
temperature
Less than 22
22.1 - 24
24.1 - 26
26.1 - 27
27.1 - 27.5
27.6 - 28
28.1 - 28.5
28.6 - 29
29.1 - 29.5
29.6 - 30
30.1 - 30.5
30.6 - 31
31.1 - 31.5
31.6 - 32
32.1 - 32.5
32.6 - 33
33.1 - 33.5
33.6 - 34
34.1 - 35
35.1 - 36
cloud cover
BLEACHING RATING
Extreme (>60% effected)
Very High (30 - 60%)
High (10-30%)
Moderate (1-10%)
no bleaching (<1% effected)
Cooktown
Cairns
Tully
Townsville
Bowen
Mackay
Rockhampton
Queensland
GBRMPA aerial survey
120 60 0 120 Kilometers
Map created by Stuart Kininmonth, Reef Futures 27th March 2002
Temperature data supplied by Remote Sensing Unit, AIMS from NOAA
AVHRR data. Coastline supplied by AUSLIG COAST100 and
reef data from GBRMPA. Bleaching survey data by Ray Berkelman.
Less tha
22.1 - 24
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27.6 - 28
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31.6 - 32
32.1 - 32
32.6 - 33
33.1 - 33
33.6 - 34
34.1 - 35
35.1 - 36
cloud co
Bleached Coral Survey
March 2002
with Three Day Average Temperatu
7th to 11th January 2002
Legend
temperature
Less than 22
22.1 - 24
24.1 - 26
26.1 - 27
27.1 - 27.5
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28.1 - 28.5
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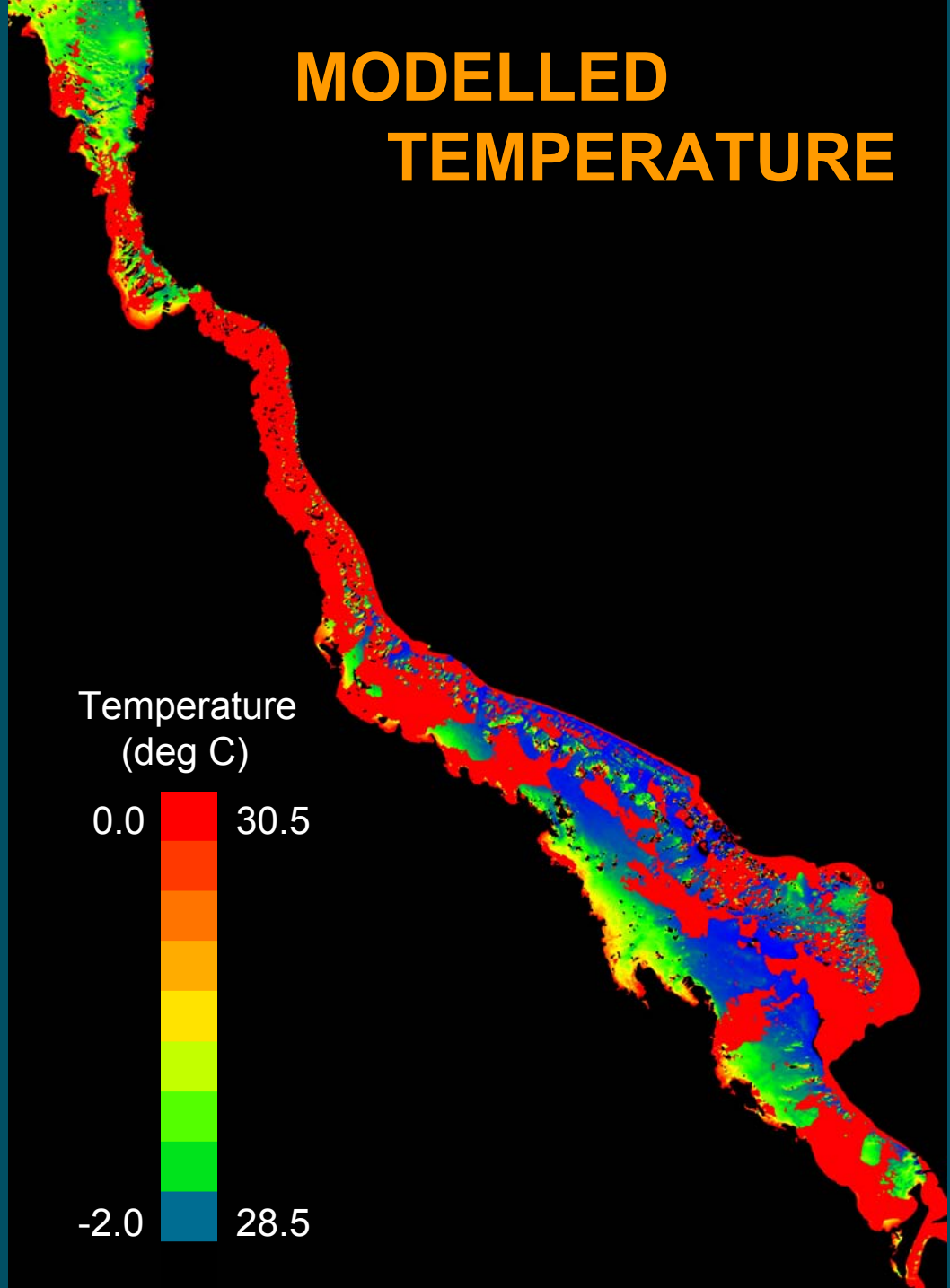


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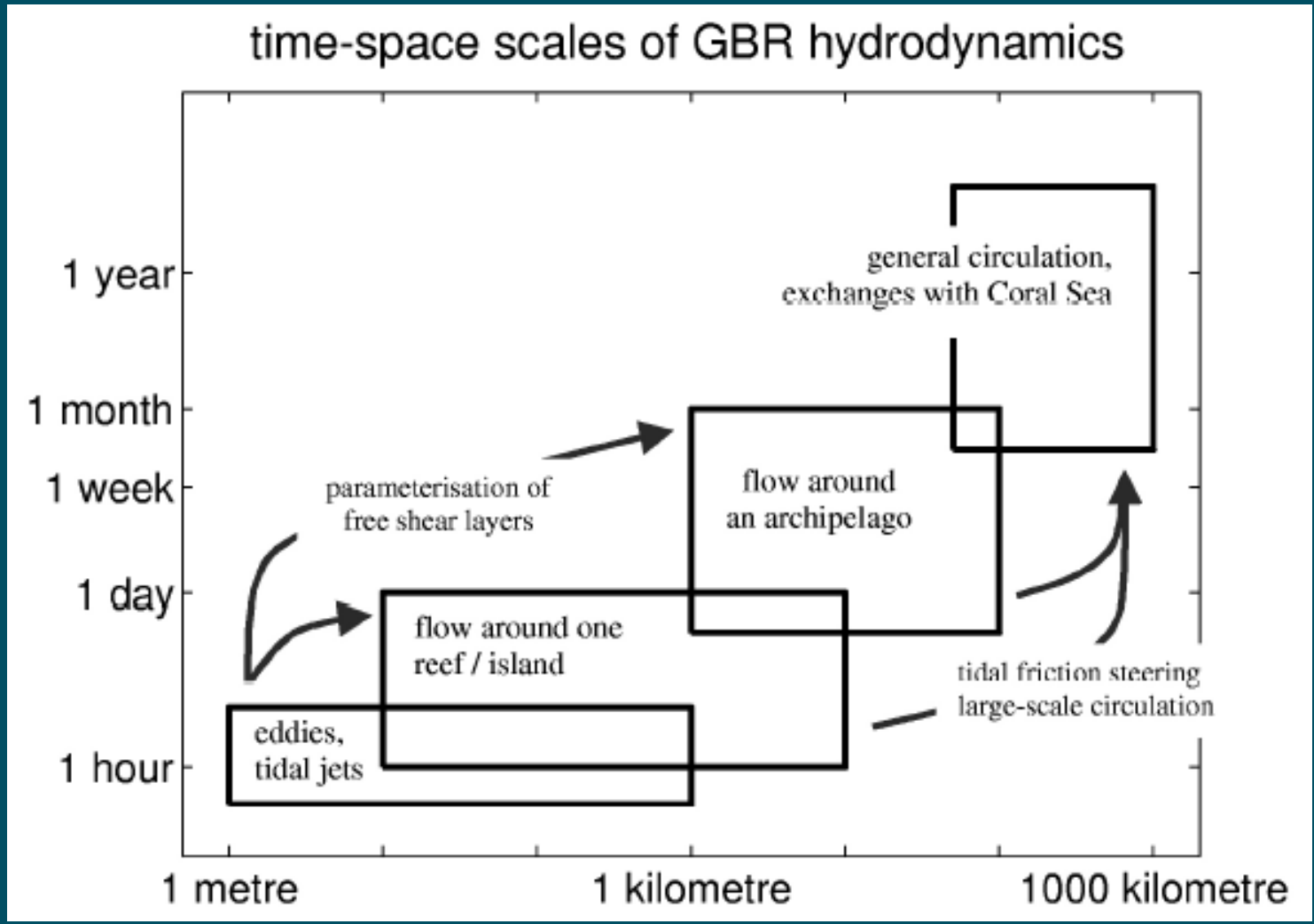


From Wolanski, et al (2002): Merging scales in models of water circulation: Perspectives from the Great Barrier Reef

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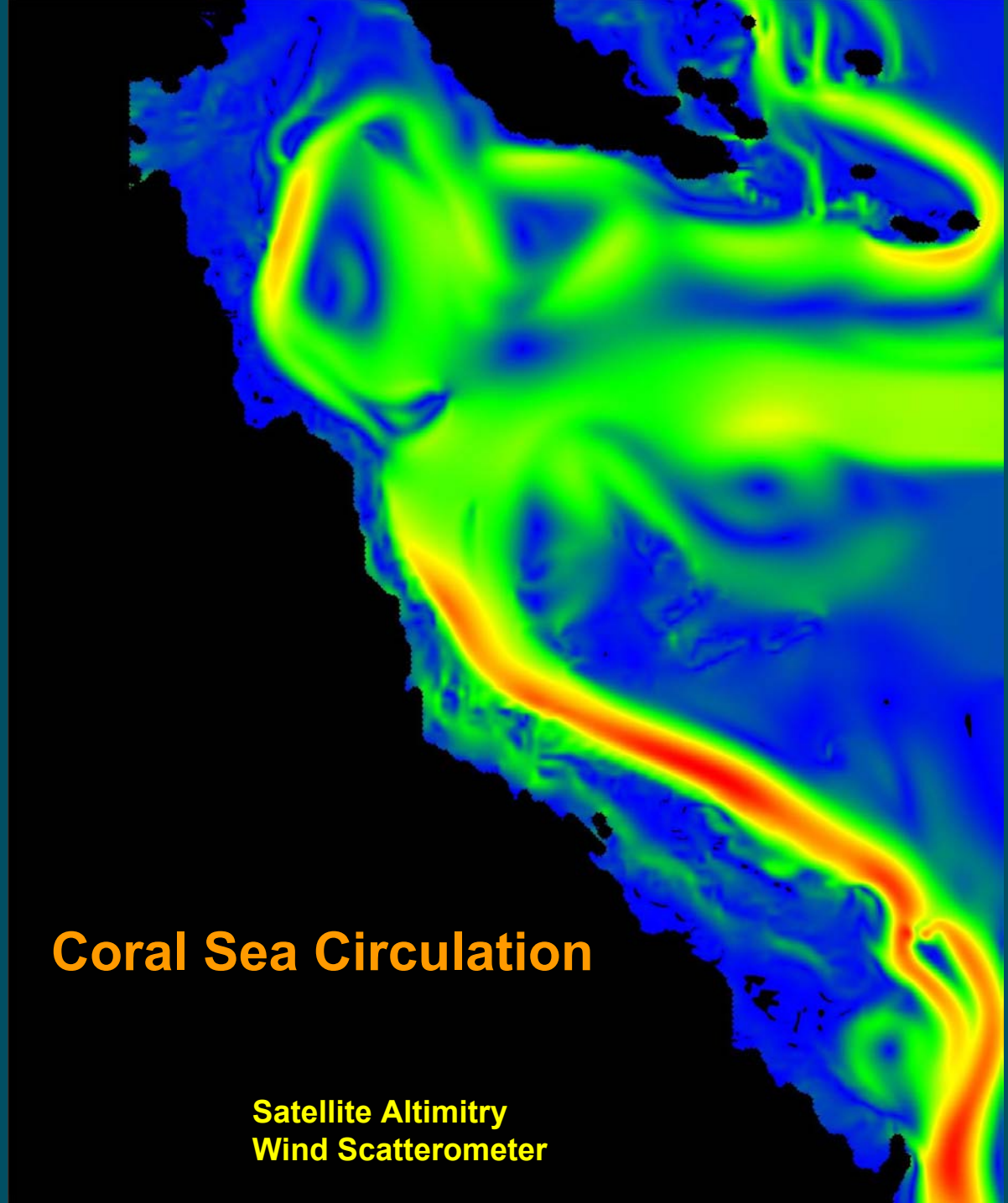

# Coral Sea Circulation

**Satellite Altimitry**
**Wind Scatterometer**

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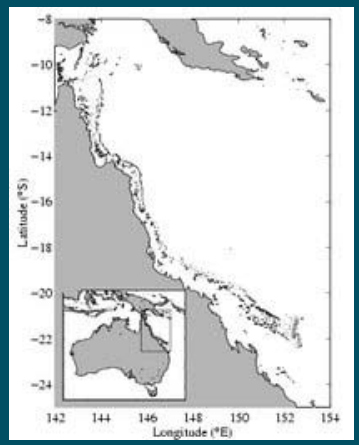
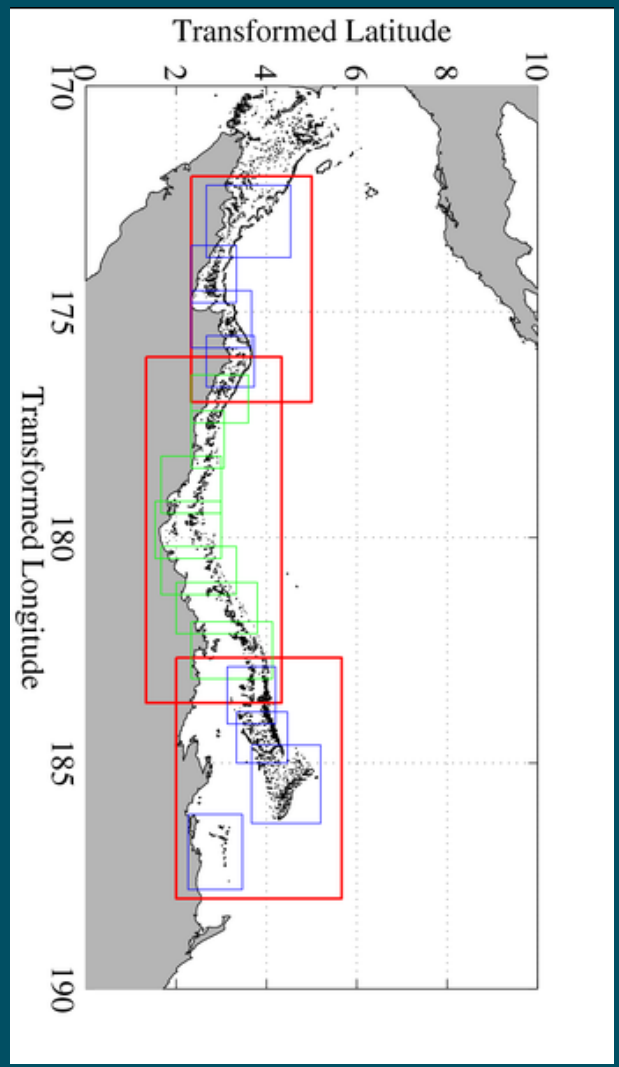
# Modelling the GBR

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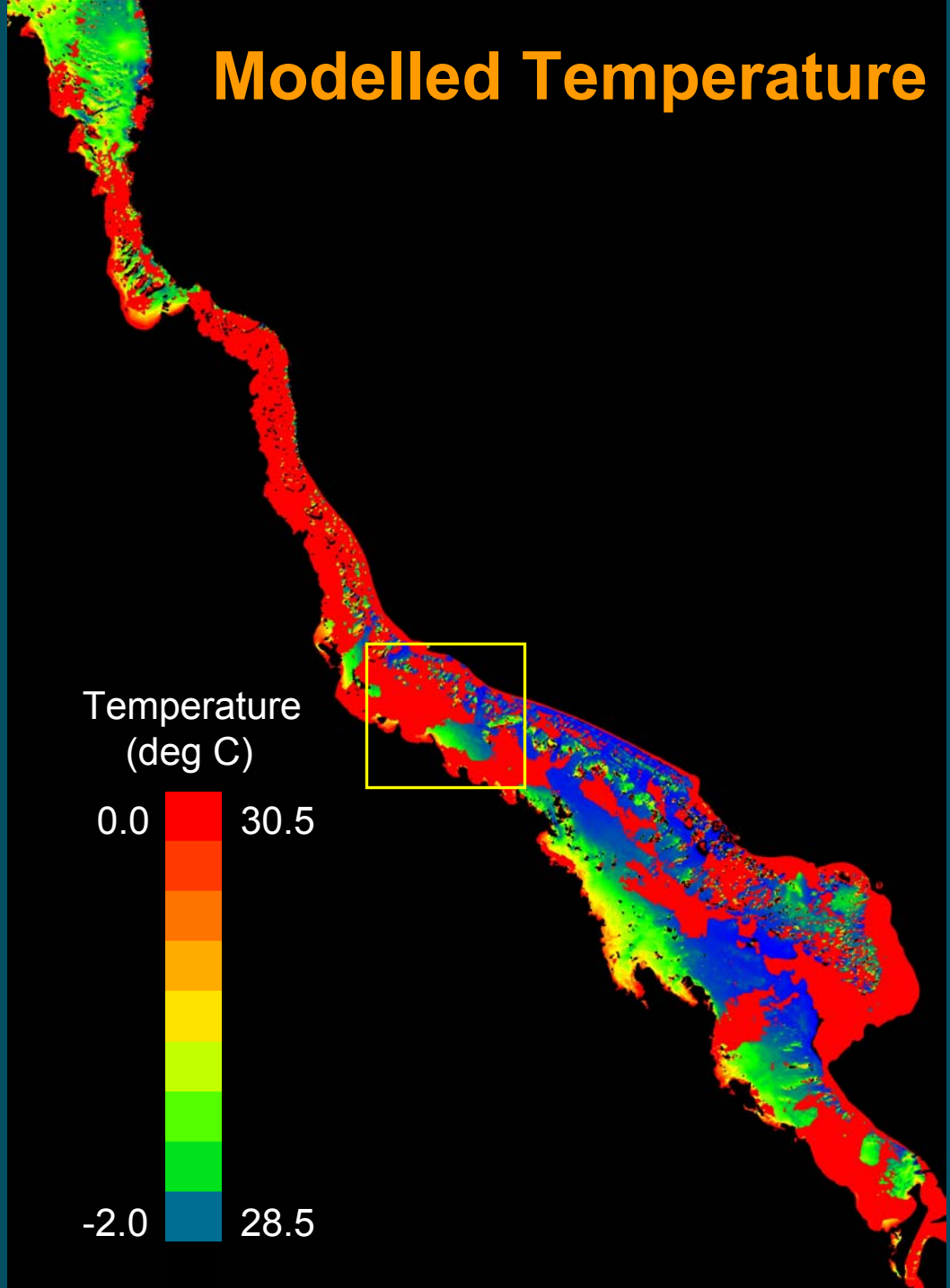
# Modelled Temperature

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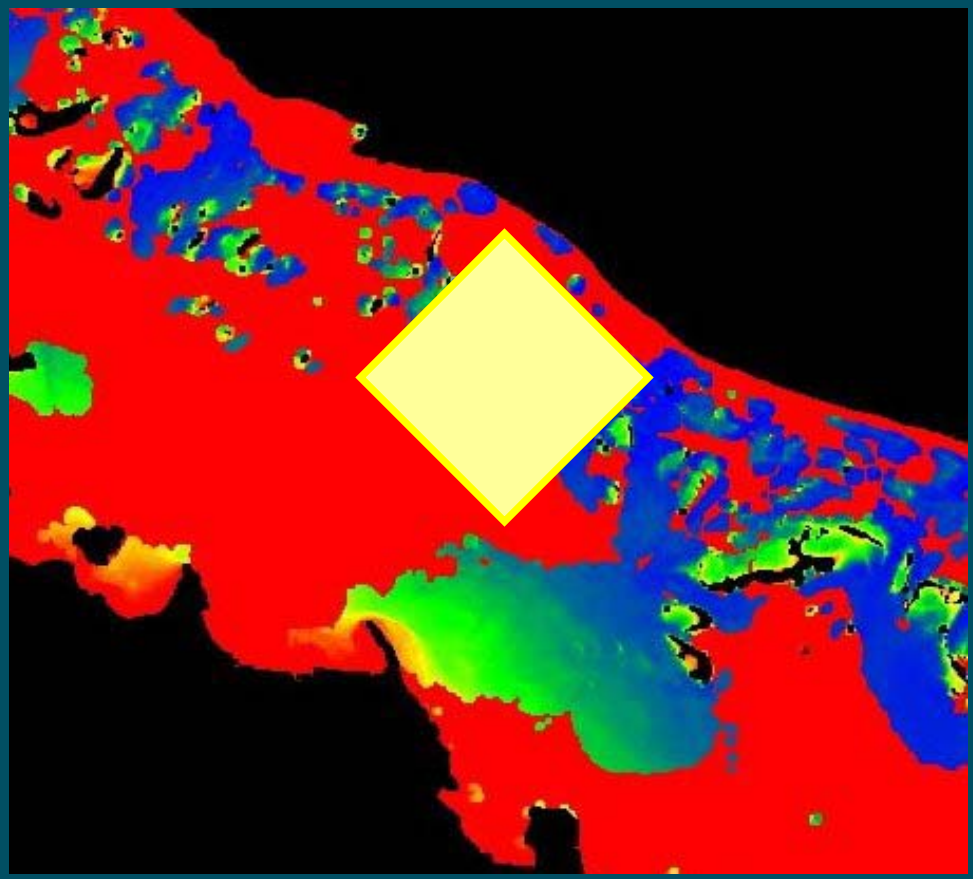
# Central GBR – modelled SST



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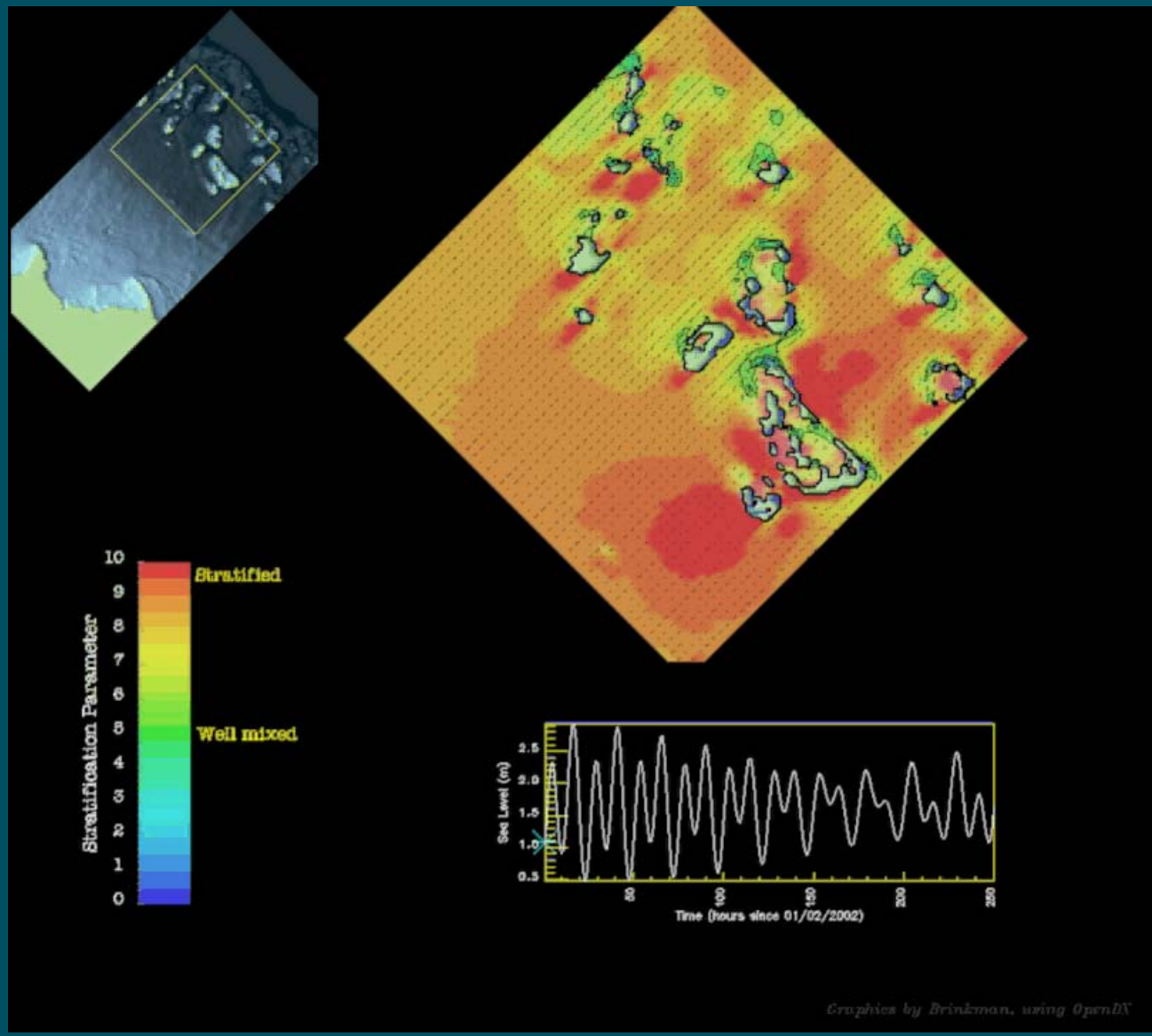
# Mixing model – Davies Reef, GBR

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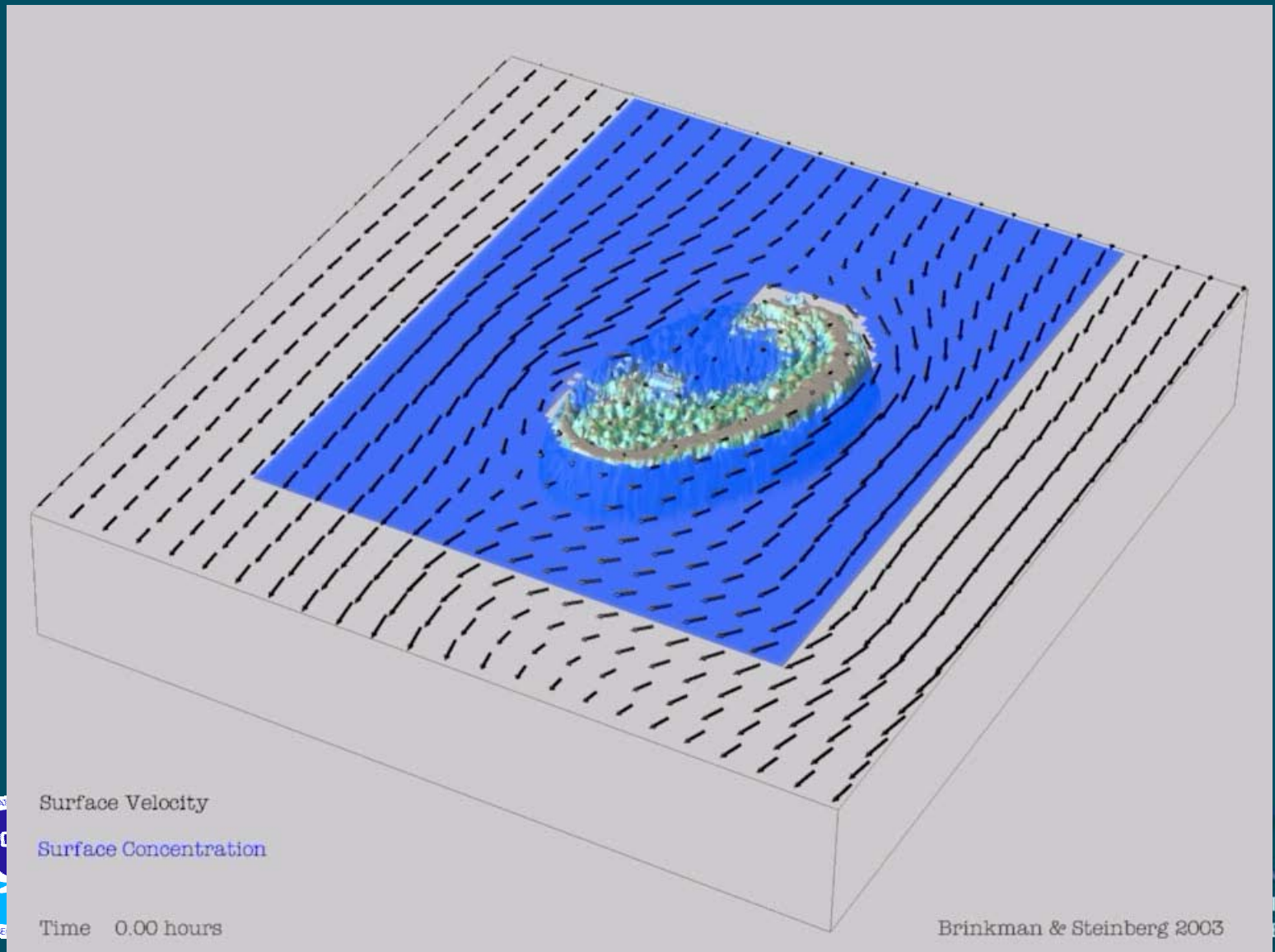
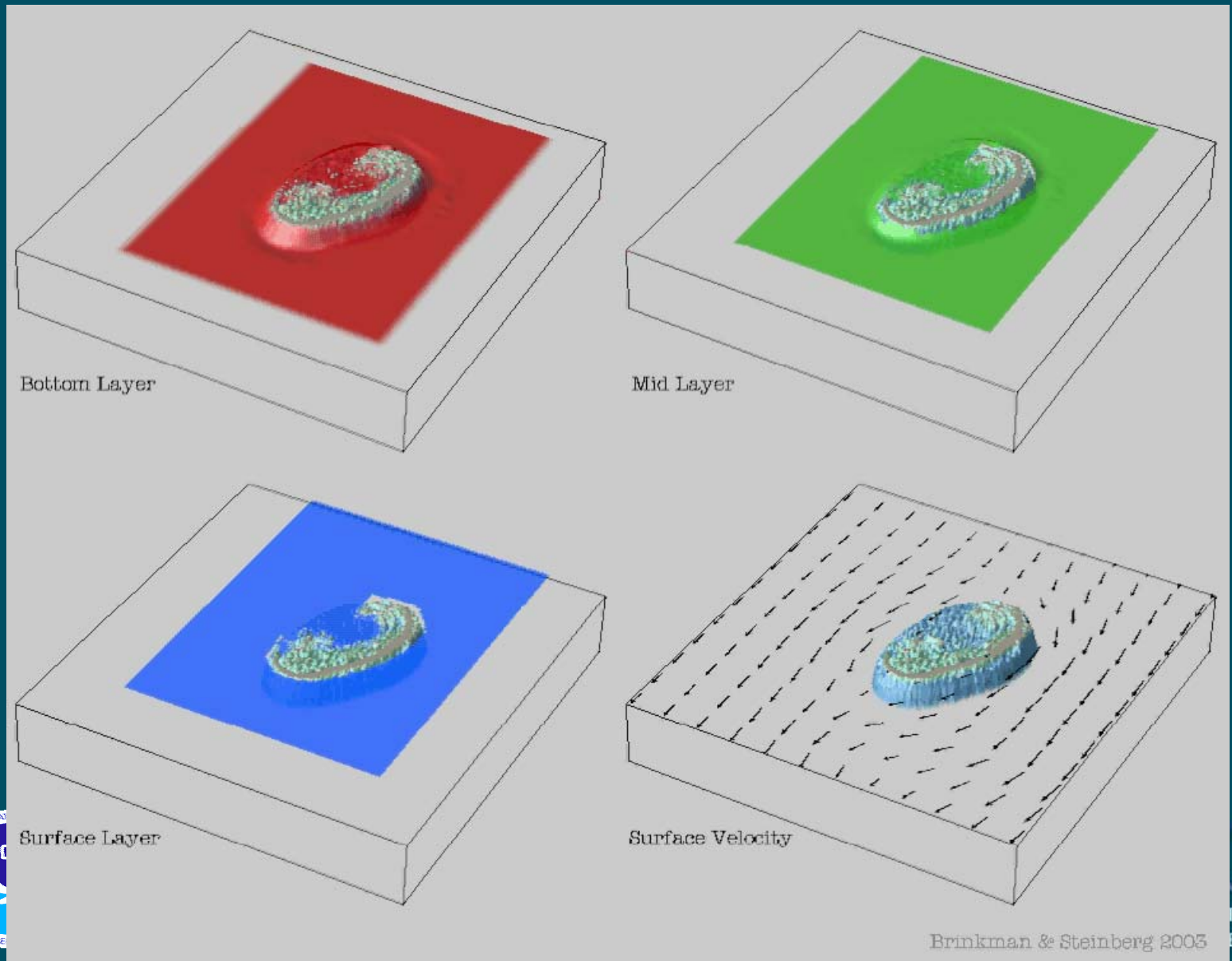
# Dispersal modelling around a reef

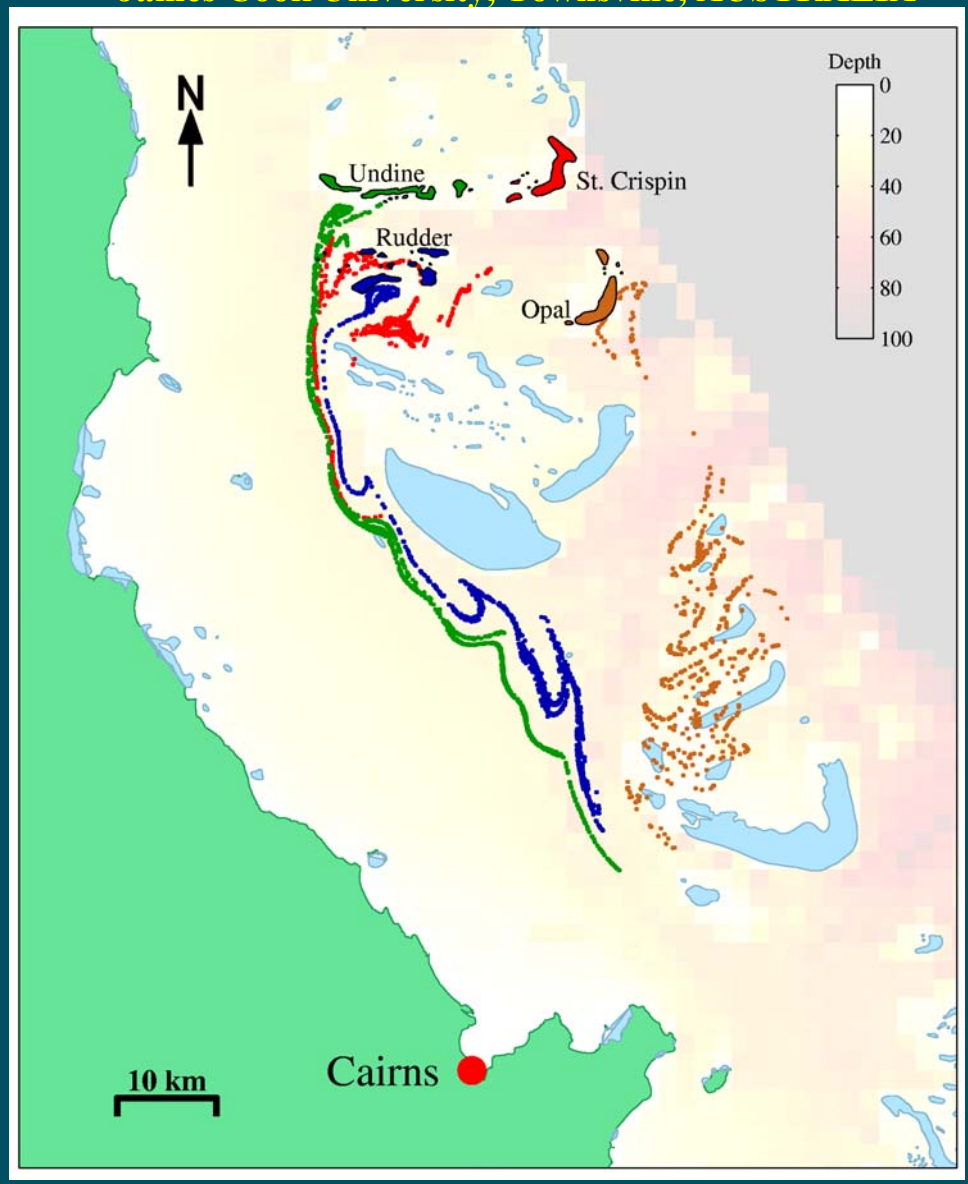


# Dispersal modeling around a reef



# CURRENT PATTERNS AND LARVAL DISPERSAL

Maurice K. James, Luciano B. Mason, Lance Bode and Paul R Armsworth
**James Cook University, Townsville, AUSTRALIA**

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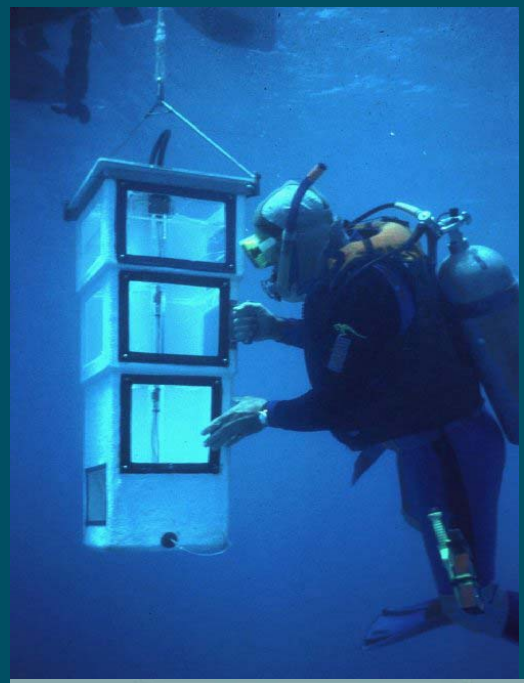
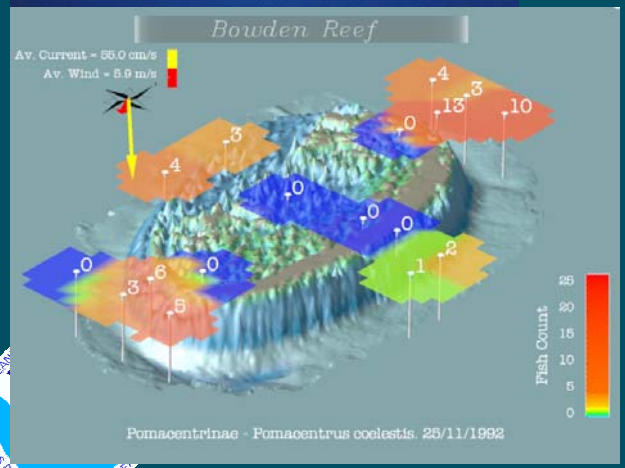
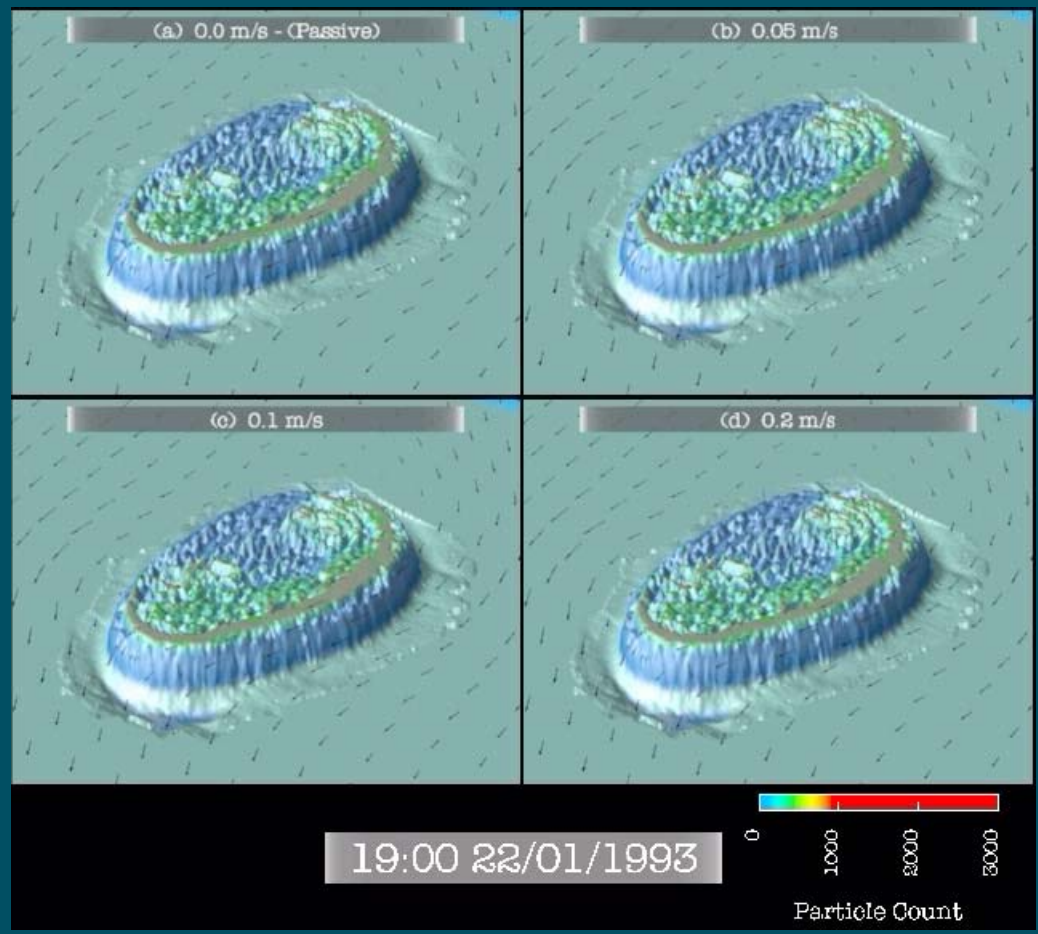
# Reef scale processes:

*Transport models for larval fishes: Recruitment patterns*



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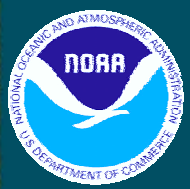
# Conclusions

## For a bleaching event …

- Calm, sunny & small tides
- Complex SST patterns are predictable
  - Potential for prediction of mass bleaching
- Hydrodynamic models
  - Need to be multi-scale
  - Useful in MPA design
  - Can explain other issues
    - Connectivity
    - Productivity issues
    - Zooxanthellae issues
    - Spawning issues

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